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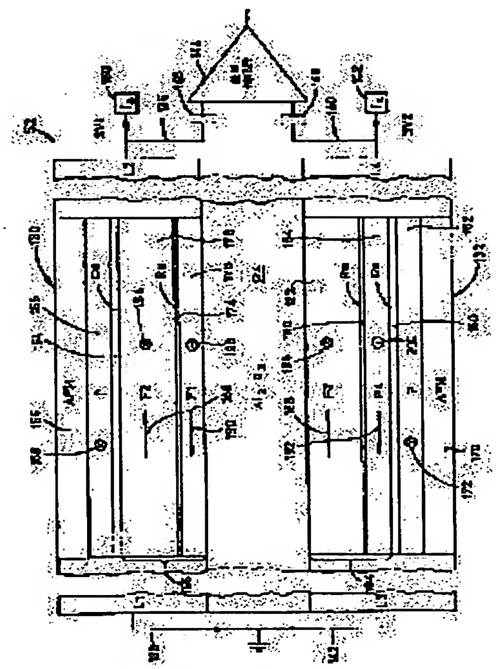
(54) MR READING HEAD, COMPOSITE HEAD CONTAINING THE SAME AND MAGNETIC DISK DRIVE CONTAINING THE SAME

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a spin-valve-sensor structure for a magnetic reading head using a first and a second spin-valve-sensors separated by an insulating gap layer.
SOLUTION: Respective spin-valve-sensors have a spacer layer 160 held between a pinning layer 162 and a laminated free layer 164. Magnetic orientations of the pinning layers are pinned in the same direction by a first and a second antiferromagnetic layers 166, 170. The first laminated free layer contains a very thin ruthenium (Ru) layer held between a first and a second ferromagnetic free layers 176, 178 and the second laminated free layer contains very thin second ruthenium (Ru) layers 174, 180 held between a third and a fourth ferromagnetic free layers 182, 184. The second ferromagnetic free layer is thicker than the first ferromagnetic free layer and the third ferromagnetic free layer is thicker than the fourth ferromagnetic free layer.



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CLAIMS

[Claim(s)]
[Claim 1] In MR read head equipped with the air bearing front face (ABS) The 1st and the 2nd spin bulb sensor which generate the response which has an opposite polarity in response to a field, The gap layer pinched between the 1st and 2nd spin bulb sensors, The 1st and 2nd leads connected to the 1st spin bulb sensor at the serial, The 1st and 3rd leads interconnect electrically including the 3rd and 4th leads connected to the 2nd spin bulb sensor at the serial. The 1st spin bulb sensor The 1st pinning layer which makes a boundary mutually [in order to form switched connection among them], and the 1st antiferromagnetism layer are included. The 2nd spin bulb sensor The 1st and 2nd antiferromagnetism layers are the MR read head characterized by carrying out pinning of the magnetic moment of the 1st and 2nd pinning layers in the same direction including the 2nd pinning layer which makes a boundary mutually [in order to form switched connection among them], and the 2nd antiferromagnetism layer.
[Claim 2] MR read head according to claim 1 characterized by the 1st and 2nd antiferromagnetism layers being the almost same ingredients which have the almost same blocking temperature.
[Claim 3] The compound MR read head and the induction write head in which an insulating stack and an induction coil are inserted between the 1st and 2nd pole pieces, and the 1st and 2nd pole pieces contain MR read head according to claim 2 characterized by opening spacing by the write-in gap layer on the air bearing front face including the induction coil with which the combined head was embedded in the insulating stack.
[Claim 4] The combined head according to claim 3 characterized by the 2nd and 4th leads connecting the 1st and 2nd spin bulb sensors to juxtaposition over the differential amplifier including the differential amplifier.
[Claim 5] The combined head according to claim 4 characterized by connecting the 1st sense current source to the 2nd lead, and connecting the 2nd sense current source to the 4th lead including the 1st and 2nd sense current sources.
[Claim 6] In the magnetic-disk drive containing a combined head according to claim 5 The magnetic disk with which a drive is supported by the rotating type on a frame and a frame, The support for supporting a combined head so that it may be attached on a frame and may become a magnetic disk and conversion relation, A means to rotate a magnetic disk, and the positioning means for connecting with a support and moving a head to two or more locations to said magnetic disk, The magnetic-disk drive characterized by including a means to be connected to a head, a means to rotate a magnetic disk, and a positioning means, to exchange a combined head and a signal, to control a motion of a magnetic disk, and to control the location of a combined head.
[Claim 7] The 1st spin bulb sensor contains the 1st nonmagnetic electric conduction spacer layer and the 1st laminating free layer. The 2nd spin bulb sensor contains the 2nd nonmagnetic electric conduction spacer layer and the 2nd laminating free layer. The 1st spacer layer should be caught between the 1st laminating free layer and the 1st pinning layer. The 2nd spacer layer should be caught between the 2nd laminating free layer and the 2nd pinning layer. The 1st laminating free layer contains the 1st ruthenium layer inserted between the 1st and 2nd ferromagnetic free layers. Including the 2nd ruthenium layer whose 2nd laminating free layer was pinched between the 3rd and 4th ferromagnetic free layers, since the 1st and 2nd ruthenium layers are thin enough The 1st and 2nd ferromagnetic free layers join together by switched connection, and the 3rd and 4th ferromagnetic free layers join together by switched connection. Since the 2nd free layer has larger magnetization than the 1st ferromagnetic free layer and the 3rd ferromagnetic free layer has larger magnetization than the 4th free layer The 1st ferromagnetic free layer follows in footsteps of magnetic rotation of the 2nd ferromagnetic free layer, and the 4th ferromagnetic free layer follows in footsteps of magnetic rotation of the 3rd ferromagnetic free layer. MR read head according to claim 1 characterized by pinching the 1st spacer layer between the 1st pinning layer and the 2nd ferromagnetic free layer, and pinching the 2nd spacer layer between the 2nd pinning layer and the 4th ferromagnetic free layer.
[Claim 8] MR read head according to claim 7 characterized by the 1st and 2nd antiferromagnetism layers being the almost same ingredients which have the almost same blocking temperature.
[Claim 9] The compound MR read head and the induction write head in which an insulating stack and an induction coil are inserted between the 1st and 2nd pole pieces, and the 1st and 2nd pole pieces contain MR read head according to claim 8 characterized by opening spacing by the write-in gap layer on the air bearing front face including the induction coil with which the combined head was embedded in the insulating stack.
[Claim 10] The combined head according to claim 9 characterized by the 2nd and 4th leads connecting the 1st and 2nd spin bulb sensors to juxtaposition over the differential amplifier including the differential amplifier.
[Claim 11] The combined head according to claim 10 characterized by connecting the 1st sense current source to the 2nd lead, and connecting the 2nd sense current source to the 4th lead including the 1st and 2nd sense current

sources.
[Claim 12] In the magnetic-disk drive containing a combined head according to claim 11 The magnetic disk with which a drive is supported by the rotating type on a frame and a frame, The support for supporting a combined head so that it may be attached on a frame and may become a magnetic disk and conversion relation, A means to rotate a magnetic disk, and the positioning means for connecting with a support and moving a head to two or more locations to said magnetic disk, The magnetic-disk drive characterized by including a means to be connected to a head, a means to rotate a magnetic disk, and a positioning means, to exchange a combined head and a signal, to control a motion of a magnetic disk, and to control the location of a combined head.
[Claim 13] MR read head according to claim 8 characterized by having the magnetic moment by which orientation of the magnetic moment of a pinning layer is perpendicularly carried out to ABS, and orientation of the 2nd and 3rd ferromagnetic free layers is carried out in the same parallel direction to ABS.
[Claim 14] MR read head according to claim 8 characterized by each ferromagnetic free layer being NiFe.
[Claim 15] MR read head according to claim 8 characterized by being the thickness each ruthenium layer of whose is 4-10A.
[Claim 16] MR read head according to claim 8 characterized by connecting the 1st sense current source to the 2nd lead, and connecting the 2nd sense current source to the 4th lead including the 1st and 2nd sense current sources.
[Claim 17] MR read head according to claim 16 characterized by having the magnetic moment by which orientation of the magnetic moment of a pinning layer is perpendicularly carried out to ABS in the same direction, and orientation of the 2nd and 3rd ferromagnetic free layers is carried out in the same parallel direction to ABS.
[Claim 18] MR read head according to claim 17 characterized by each ferromagnetic free layer being NiFe.
[Claim 19] MR read head according to claim 18 characterized by being the thickness each ruthenium layer of whose is 4-10A.
[Claim 20] The compound MR read head and the induction write head in which an insulating stack and an induction coil are inserted between the 1st and 2nd pole pieces, and the 1st and 2nd pole pieces contain MR read head according to claim 19 characterized by opening spacing by the write-in gap layer on the air bearing front face including the induction coil with which the combined head was embedded in the insulating stack.
[Claim 21] The combined head according to claim 20 characterized by the 2nd and 4th leads connecting the 1st and 2nd spin bulb sensors to juxtaposition over the differential amplifier including the differential amplifier.
[Claim 22] In the magnetic-disk drive containing a combined head according to claim 21 The magnetic disk with which a drive is supported by the rotating type on a frame and a frame, The support for supporting a combined head so that it may be attached on a frame and may become a magnetic disk and conversion relation, A means to rotate a magnetic disk, and the positioning means for connecting with a support and moving a head to two or more locations to said magnetic disk, The magnetic-disk drive characterized by including a means to be connected to a head, a means to rotate a magnetic disk, and a positioning means, to exchange a combined head and a signal, to control a motion of a magnetic disk, and to control the location of a combined head.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] More specifically, this invention relates to the reproducing head which uses one pair of spin bulbs for differential detection and common mode removal about differential spin bulb sensor structure.
[0002]
[Description of the Prior Art] In order to sense the field from movable magnetic media, such as a magnetic disk or a magnetic tape, the read head uses a spin bulb sensor. Such a sensor contains the nonmagnetic conductive layer (henceforth a spacer layer) inserted between the 1st and 2nd ferromagnetic layers (henceforth a pinning layer and a free layer). The 1st and 2nd leads are connected to the spin bulb sensor in order to conduct the sense current which passes along it. Pinning of the magnetization of a pinning layer is carried out to the include angle of 90 degrees to magnetization of a free layer, and magnetization of a free layer can react freely to an external magnetic field. Pinning of the magnetization of a pinning layer is usually carried out by switched connection with an antiferromagnetism layer. The thickness of a spacer layer is chosen so that it may become smaller than the mean free path of the conduction electron which passes along a sensor. In this arrangement, some conduction electron is scattered about according to a boundary with a spacer layer, a pinning layer, and a free layer. When magnetization of a pinning layer and a free layer is mutually parallel, dispersion becomes the minimum, and dispersion becomes the maximum when magnetization of a pinning layer and a free layer is reverse parallel. Change of dispersion changes resistance of a spin bulb sensor in proportion to costheta. In this case, theta is an include angle during magnetization of a pinning layer and a free layer. A spin bulb sensor has a magnetic-reluctance (MR) multiplier quite higher than an anisotropy magnetic-reluctance (AMR) sensor. For this reason, this sensor may be called giant magnetic reluctance or a huge magnetic-reluctance (GMR) sensor.
[0003] The read head (henceforth the "spin bulb read head") which uses a spin bulb sensor can be combined with the induction write head, and a combined head can be formed. A combined head can have the structure of either an integrated head or a piggyback head. The monolayer of an integrated head functions as shielding of the read head, and the 1st pole piece of the write head. A piggyback head has a layer according to individual which functions as the 1st pole piece of the write head. In the magnetic-disk drive, in order to write information in a disk, or in order to read information in a disk, the air bearing front face (ABS) of a combined head adjoins a rotation disk, and is supported. Information is written in a rotation disk by the field which borders the gap between the 1st of the write head, and the 2nd pole piece. In read mode, resistance of a spin bulb sensor changes in proportion to the magnitude of the field from a rotation disk. If a sense current conducts through a spin bulb sensor, by change of resistance, change of potential occurs, and it will be detected as a regenerative signal and will be processed.
[0004] The method for increasing the signal-to-noise ratio of a spin bulb head is using the 1st and 2nd spin bulb sensors by which differential detection is carried out for common mode noise removal. Each spin bulb sensor contains the thin nonmagnetic conductive layer inserted between the free layer and the pinning layer. In order to make it this method function, pinning of the pinning layer of each other must be carried out to reverse parallel. In this, it must build with the separate ingredient which has blocking temperature which is different in the antiferromagnetism layer which carries out pinning of the pinning layer. An antiferromagnetism layer with blocking temperature lower than it is built so that magnetic orientation of the antiferromagnetism layer which built the antiferromagnetism layer with the highest blocking temperature first, next was built first may not be changed. Though regrettable, in order to attain the above-mentioned method, various ingredients which have different enough blocking temperature are not known now.
[0005]
[Problem(s) to be Solved by the Invention] A one division target of this invention is to offer the spin bulb read head which uses the 1st and 2nd spin bulb sensors for differential detection of the impressed field.
[0006] Other purposes are to offer the spin bulb read head which uses the 1st [which has the 1st of the almost same ingredient which has the almost same blocking temperature, and the 2nd antiferromagnetism layer], and 2nd spin bulbs.
[0007] Other purposes are to offer the spin bulb sensor which performs common mode removal and a strengthening signal output.
[0008] Other purposes are to offer the spin bulb read head which improves the S/N of a ****** signal sharply compared with the spin bulb read head of the advanced technology.
[0009] Other purposes are to offer the spin bulb read head in which 10 Gb/two or more inches surface density is

possible.
[0010]
[Means for Solving the Problem] The spin bulb structure which uses the 1st and 2nd spin bulb sensors which generate the response of antipole nature in response to a polar field with single this invention is offered. An antipole nature response is processed by the differential amplifier for common mode removal of a noise, and generation of a strengthening composite signal. The 1st and 2nd spin bulb sensors are magnetically separated by the gap layer. The 1st spin bulb sensor is connected with the 1st and 2nd leads at a serial, and the 2nd spin bulb sensor is connected with the 3rd and 4th leads at the serial. The 2nd and 4th leads interconnect electrically, and the 1st and 3rd leads can be connected now to the differential amplifier. The 1st spin bulb sensor contains the 1st nonmagnetic electric conduction spacer layer inserted between the 1st laminating free layer and the 1st ferromagnetic pinning layer. The 2nd spin bulb sensor contains the 2nd nonmagnetic electric conduction spacer layer inserted between the 2nd laminating free layer and the 2nd ferromagnetic pinning layer. The orientation of the magnetic moment of the 1st and 2nd pinning layers is mutually parallel, and pinning is perpendicularly carried out by the 1st and 2nd antiferromagnetism layers to the air bearing front face (ABS) of the read head which moreover adopted spin bulb structure, respectively.
[0011] The 2nd laminating free layer contains the 2nd very thin ruthenium (Ru) layer pinched between the 3rd and 4th ferromagnetic free layers including the 1st very thin ruthenium (Ru) layer whose 1st laminating free layer was pinched between the 1st and 2nd ferromagnetic free layers. Since each of the 1st and 2nd ruthenium layers has thickness of about 4-10A about, switched connection of the 1st and 2nd free layers is carried out powerfully, each magnetic moment becomes reverse parallel mutually, switched connection of the 3rd and 4th free layers is carried out powerfully, and each magnetic moment becomes reverse parallel mutually. The magnetic moment of the 1st, 2nd, 3rd, and 4th ferromagnetic free layer has parallel sense to ABS. Therefore, if a field exists, the magnetic moment of the 1st and 2nd free layers will rotate together, and the magnetic moment of the 3rd and 4th free layers will rotate together. Since the 2nd and 3rd ferromagnetic free layers are thicker than the 1st and 4th ferromagnetic free layers respectively, the magnetic moment of the 2nd and 3rd ferromagnetic free layers answers a field, and is rotated, and the magnetic moment of the 1st and 4th ferromagnetic free layers follows in footsteps.
[0012] Since the 1st spacer layer is pinched between the 1st pinning layer and the 2nd ferromagnetic free layer and the 2nd spacer layer is pinched between the 2nd pinning layer and the 4th ferromagnetic free layer If the impressed field exists, the 1st spin bulb effectiveness will occur between the 1st pinning layer of the 1st spin bulb, and the 2nd ferromagnetic free layer, and the 2nd spin bulb effectiveness will occur between the 2nd pinning layer of the 2nd spin bulb, and the 4th ferromagnetic free layer. The 1st and 3rd ferromagnetic free layers exceed the mean free path of conduction electron, and do not contribute to the spin bulb effectiveness. As above-mentioned, the orientation of the magnetic moment of the 1st and 2nd pinning layers is parallel, and perpendicular to ABS. The orientation of the magnetic moment of the 2nd and 4th ferromagnetic free layers is reverse parallel mutually, and is parallel to ABS. Therefore, if a field exists, the magnetic moment of the 2nd ferromagnetic free layer will be rotated to an one direction to the magnetic moment of the 1st pinning layer, and the magnetic moment of the 4th ferromagnetic free layer will be rotated to an opposite direction to the magnetic moment of the 2nd pinning layer. Consequently, the 1st spin bulb generates one polar reply signal, and the 2nd spin bulb generates the reply signal of antipole nature. Next, these reply signals are processed by the differential amplifier for common mode removal and a strengthening signal output. In the above-mentioned arrangement, the 1st and 2nd antiferromagnetism layers are made of the same ingredient which has the same blocking temperature. The 1st and 2nd laminating free layers are enough indicated by U.S. Pat. No. 5408377 transferred to these people. Since magnitude is the combination of two or more layers equipped with the antiparallelism magnetization which is not equal, generally this laminating free layer is called "synthetic ferrimagnetic substance (synthetic ferrimagnet)."
[0013] The above and other the purposes and advantages of this invention will become clearer if the following explanation is read with an accompanying drawing.
[0014]
[Embodiment of the Invention] Next, although an accompanying drawing is referred to, the same reference number used with two or more drawings shows the same part or the same part, and the magnetic-disk drive 30 is shown in drawing 1 , drawing 2 , and drawing 3 . Drive 30 contains the spindle 32 which supports a magnetic disk 34 and is rotated. A spindle 32 is rotated by the motor 36 and this motor is controlled by the motor controller 38. Although the magnetic head 40 can be used as record and the integrated MR head for read, it is attached on a slider 42 and this slider is supported by the suspension 43 and the actuator arm 44. As shown in drawing 3 , in a mass direct access storage device (DASD), two or more disks, a slider, and a suspension can be used. A suspension 43 and an actuator arm 44 position a slider 42 so that it may become the front face and conversion relation of a magnetic disk 34 and the magnetic head 40 may be arranged. If a disk 34 rotates by the motor 36, a slider 42 will be supported by the air bearing front face (ABS) 46 on the thin (usually 0.075 micrometers) cushion of air (air bearing). Next, in order to write information in two or more annular trucks on the front face of a disk, and in order to read information in there, the magnetic head 40 is used. The processing circuit 48 exchanges the signal showing said information for a head 40, outputs a motorised signal, and outputs the control signal for moving a slider 42 to various trucks.
[0015] Drawing 4 is the side-face sectional view of integrated MR head 50 which has a write head part and a read head part, and a read head part uses the sensor structure which took in the double (dual) spin bulb MR sensor 52 by this invention. MR head 52 is pinched between the 1st and 2nd gap layers 54 and 56, and the 1st and 2nd gap layers are pinched between the 1st and 2nd shielding layers 58 and 60. An external magnetic field is answered and

resistance of the MR sensor 52 changes. According to the sense current conducted through the sensor, such change becomes clear as change of potential. Change of such potential is processed by the processing circuit 48 shown in drawing 3 .
[0016] The write head part of a head contains the coil layer 64 pinched between the 1st and 2nd insulating layers 66 and 68. A head can be flattened using the 3rd insulating layer 70, and the ripple of the 2nd insulating layer generated by the coil layer 64 can be removed. The coil layer 64 and the 1st, 2nd, and 3rd insulating layer 66, 68, and 70 are inserted between the 1st and 2nd pole piece layers 72 and 74. It is separated by the write-in gap layer 76 of ABS, and the electromagnetic coupling of the 1st and 2nd pole piece layers 72 and 74 is carried out about the posterior part gap (not shown) which set spacing from ABS. The 1st and 2nd soldered-joint sections 80 and 82 connect the lead (not shown) from the MR sensor 52 to the lead on a suspension 43 (not shown), and the 3rd and 4th soldered-joint sections 84 and 86 connect the lead (not shown) from a coil 64 to the lead on a suspension (not shown) as shown in drawing 2 .
[0017] Drawing 7 shows the example 100 of the advanced technology of the magnetic-reluctance (MR) spin bulb sensor explained as a background of the double spin bulb sensor 52 of this invention indicated below. The MR sensor 100 has the 1st and 2nd ferromagnetic layers which are the free layer 102 and the pinning layer 104. The nonmagnetic electric conduction spacer layer 106 is pinched between the free layer 102 and the pinning layer 104. Since the antiferromagnetism (AFM) layer 108 has the film front face which touches the film front face and boundary of the pinning layer 104, pinning of the magnetization 110 of the pinning layer 104 is carried out in the predetermined directions, such as a perpendicular, to ABS by switched connection with the antiferromagnetism layer 108. The free layer 102 has the magnetization 111 which can rotate freely in response to the effect of the field signal from a rotation disk. The free layer 102 and the pinning layer 104 are usually made from a permalloy (NiFe), and the spacer layer 106 is usually made from copper. The antiferromagnetism layer 108 can be made from the ingredient chosen from the group who consists of NiMn and FeMn. Electrical connection of the 1st and 2nd leads 112 and 114 is carried out to the sensor 100 by suitable means, such as a continuation joint, so that spacing during a lead may define the width of recording track of the read head. In order to supply the sense current (Is) conducted through a spin bulb sensor, electrical connection of the sense current source 118 is carried out to the 1st and 2nd leads 112 and 114. The sensing circuit 120 of the sense current source 118 and juxtaposition is for sensing change of the potential in the spin bulb sensor 100 when guiding a field signal in a spin bulb sensor with the rotation disk 34 shown in drawing 1 . The sense current source 118 and the sensing circuit 120 are a part of processing circuits 48 of drawing 3 .
[0018] Each of layers 102, 104, 106, and 108 conducts a part of sense current between the 1st and 2nd leads 112 and 114. The important parameter of actuation of a spin bulb sensor is having thickness with the spacer layer 106 smaller than the mean free path of the conduction electron which flows between the 1st and 2nd leads 112 and 114. Although the degree of electronic dispersion is decided by whenever [angular relation / of the magnetization 111 of the free layer 102, and the magnetization 110 of the pinning layer 104], it determines the resistance of MR sensor to the sense current Is. The maximum resistance corresponding to the maximum dispersion and it is generated when magnetization 110 and 111 is reverse parallel, and the minimum drag corresponding to the minimum dispersion and it is generated when magnetization 110 and 111 is mutually parallel. Since orientation is usually carried out in parallel to ABS, if, as for the magnetization 111 of the free layer 102, forward [a rotation disk to] and a negative field signal are received, magnetization 111 will rotate facing up or downward, and will increase or decrease resistance of a sensor. This should become an opposite situation when orientation of the magnetization 110 of the pinning layer 104 is carried out to the sense which does not go to ABS but separates from ABS.
[0019] The spacer layer 106 is thin, since the layer is coarse, the ferromagnetic association HFC occurs and this is guided to the free layer 102 by the pinning layer 104 on a boundary with the pinning layer 104. Another field which acts on the free layer 102 is a demagnetization field from the pinning layer 104, and this causes the induction demagnetization field HDEMAG on a free layer. As a spin bulb sensor shows drawing 4 , when centering of this is carried out between the 1st and 2nd shielding layers 58 and 60, it is usually set to about 51 Oe(s). Since the above-mentioned field can be made in order to offset each other mutually substantially by controlling appropriately the thickness of layers 102, 104, and 106, and the amount of the sense current Is, when the read head is a quiescent state, as shown in (there is no signal impressed although there was a sense current), and drawing 7 , the magnetic moment 111 of a free layer becomes ABS and parallel.
[0020] The problem of the spin bulb sensor 100 of the advanced technology shown in drawing 7 is that the noise which a sensor picks up is processed with a signal. It must be desirable, if this noise can be reduced or removed in order to raise a signal-to-noise ratio (SNR). If the sensor 100 of one pair of advanced technology can be used appropriately, common mode noise removal should be able to remove the noise. The sensor of one pair of these advanced technology must be needed in order to answer one polar field and to generate the signal of antipole nature. The reply signal should be processed by the differential amplifier, in order to remove common mode noise and for this to raise SNR. It is thought that it is necessary to carry out pinning of it to reverse parallel although a pinning layer shows one of them to 104 of drawing 7 . [each other] For this reason, the antiferromagnetism layer which shows one of them to 108 of drawing 7 is set up by the magnetic orientation from which about 180 degrees of phases separated mutually.
[0021] Orientation of magnetization is set up by impressing a field towards a request during manufacture and a heating phase at a layer. For example, when an antiferromagnetism layer is FeMn, the magnetic orientation should be established during manufacture by heating a layer to 200 degrees C, and it is exposed to the field of the direction of

desired. This level of 200 degrees is called blocking temperature of FeMn. When two antiferromagnetism layers are made of the same ingredient, it is thought impossible to carry out orientation of the magnetization to reverse parallel mutually. Both of the antiferromagnetism layers are exposed to the same field as the same temperature. Therefore, if an antiferromagnetism layer has different enough blocking temperature so that the magnetic orientation can be mutually established to reverse parallel, it must be desirable. As for one pair of such ferromagnetic layers that have different enough blocking temperature, current and existence are not known. Therefore, although common mode noise removal was a desirable function for the spin bulb read head, since the ingredient required for the ferromagnetic layer was lacked, it was frustration.

[0022] As shown in drawing 4 , drawing 5 , and drawing 6 , the 1st and 2nd spin bulb sensors 130 and 132 separated by a gap or insulating layers 134, such as aluminum 2O3, are used for the spin bulb read head 52 of this invention. As shown in drawing 6 , the 1st spin bulb sensor 130 is connected with the 1st and 2nd leads 136 and 138 at a serial, and the 2nd spin bulb sensor 132 is connected with the 3rd and 4th leads 140 and 142 at the serial. The type of connection can be made into a continuation joint as shown in drawing 6 . Leads 138 and 142 can interconnect in a ground, and can connect leads 136 and 140 over the differential amplifier 144 with the 1st and 2nd capacitors 146 and 148. Since the 1st and 2nd sense current sources 150 and 152 are connected to the 2nd and 4th leads 136 and 140, respectively, the sense current Is is conducted to a ground through each spin bulb sensor 130 and 132. In the desirable example, the sense current Is is equal and resistance of the 1st and 2nd sensors 130 and 132 becomes equal at the time of a quiescent state (with no sense current). Since the spin bulb sensors 130 and 132 are constituted so that the reply signal which has antipole nature may be generated, in order to attain common mode noise removal, they can process a reply signal discriminatorily with the differential amplifier 144. The differential amplifier 144 is a part of processing circuit 48 shown in drawing 3 . The reply signal from which it was generated by the spin bulb sensors 130 and 132, and about 180 degrees of phases separated is added by the differential amplifier 144, and common mode noise is negated.

[0023] The spin bulb sensor 130 contains the 1st thin spacer layer 154 inserted between the pinning layer 156 and the laminating free layer 158. The spin bulb sensor 132 contains the thin spacer layer 160 pinched between the pinning layer 162 and the laminating free layer 164. The spin bulb sensor 130 contains further the antiferromagnetism layer (AFM) 166 which becomes a boundary with the pinning layer 156, in order to carry out pinning of the magnetic orientation toward the back of space by switched connection, as an arrow head 168 shows. Similarly, the spin bulb sensor 132 contains the antiferromagnetism layer (AFM) 170 which becomes a boundary with the pinning layer 162, in order to carry out orientation of the magnetization of the pinning layer toward the back of space by switched connection, as an arrow head 172 shows. In this invention, since the antiferromagnetism layers 166 and 170 are built with the same ingredients, such as FeMn which has the same blocking temperature, the magnetic orientation 168 and 172 becomes parallel mutually, and they become perpendicular to ABS preferably. If required, it is arbitrary and the magnetic orientation 168 and 172 can also be turned out of space. In this arrangement, by exposing the antiferromagnetism layers 166 and 170 to 200-degree C heat under the field turned out of space, while the magnetic orientation of the antiferromagnetism layers 166 and 170 manufactures, it is established.

[0024] The laminating free layer 158 contains the very thin ruthenium (Ru) layer 174 pinched between the 1st and 2nd ferromagnetic free layers 176 and 178. The laminating free layer 164 contains the very thin ruthenium (Ru) layer 180 pinched between the 3rd and 4th ferromagnetic free layers 182 and 184. The ruthenium layers 174 and 180 have the thickness of the range of 4A - 10A. Strong switched connection exists between the 1st and 2nd ferromagnetic free layers 176 and 178 and among the ferromagnetic free layers 182 and 184. It is important that the 2nd ferromagnetic free layer 178 is thicker than the 1st ferromagnetic free layer 176, and the 3rd ferromagnetic free layer 182 is thicker than the 4th ferromagnetic free layer 184 a case to indicate below.

[0025] During manufacture, as the magnetic moments 186 and 188 show, the orientation of the magnetic moment of the 2nd and 3rd ferromagnetic free layers 178 and 182 is mutually parallel, and is aligned in the same parallel direction to ABS. Such the magnetic moment is arbitrary and can also be aligned to an opposite direction. Since the 2nd ferromagnetic free layer 178 is the antiferromagnetic substance by which switched connection was carried out to the 1st ferromagnetic free layer 176, the magnetic moment 190 of the 1st ferromagnetic free layer 176 is reverse parallel to the magnetic moment 186. Since similarly the 3rd ferromagnetic free layer 182 is the antiferromagnetic substance by which switched connection was carried out to the 4th ferromagnetic free layer 184, the magnetic moment 192 of the 4th ferromagnetic free layer is reverse parallel to the magnetic moment 188 of the 3rd ferromagnetic free layer. When the read head 52 is a quiescent state (i.e., although a sense current is conducting, when the signal is not impressed), the magnetic orientation of a free layer becomes as it is shown in 186, 188, 190, and 192. If it excites with the field signal from a rotation disk, these magnetic moments will be relatively rotated to the fixed magnetic moments 168 and 172 of the pinning layers 156 and 162. The spin bulb effectiveness of the 1st spin bulb 130 is between relative rotations with the magnetic moment 186 of the 2nd ferromagnetic free layer 178, and the magnetic moment 168 of the pinning layer 156, and carries out chisel generating. Since the 1st free layer 176 is rotated on the outside of the mean free path of the conduction electron of a sense current, rotation of the magnetic moment 190 does not do any effect to the spin bulb effectiveness. Similarly, rotation of the magnetic moment 192 of the 4th [to the magnetic moment 172 of the pinning layer 162] ferromagnetic free layer 184 causes the spin bulb effectiveness of the spin bulb sensor 132. Similarly, since the 3rd ferromagnetic free layer 182 exceeds the mean free path of the conduction electron of a sense current, rotation of the magnetic moment 188 does not do any effect to the spin bulb effectiveness.

[0026] If the field from a rotation disk is detected, the free layers 178 and 182 of the thicker one will be rotated in the same direction. Since switched connection of the ferromagnetic free layers 176 and 184 of the thinner one is strongly carried out to the layers 178 and 182 of the thicker one, the magnetic moments 190 and 192 follow in footsteps of the magnetic moments 186 and 188, respectively. The force of the switched connection of the thick layer and thick film of each spin bulb sensor is about 10,000 Oe(s). F1 carries out antiparallelism association firmly to F2, and F3 is carrying out antiparallelism association firmly to F4 similarly. These layers maintain antiparallelism magnetization orientation, answering a field. If it assumes that the field is turned toward the back of space, the magnetic moment 186 of the 2nd ferromagnetic free layer 178 will be rotated toward the back of space so that it may be in a saturation state, as an arrow head 194 shows. Resistance of the spin bulb sensor 130 becomes min for the magnetic moment 194 of the 2nd ferromagnetic free layer to be parallel to the magnetic moment 168 of the pinning layer 156. The magnetic moment 190 of the ferromagnetic free layer 176 is rotated to an opposite direction to the magnetic moment 186 of the 2nd ferromagnetic free layer 178, as an arrow head 196 shows. Similarly, if a signal is impressed toward the back of space, the magnetic moment 188 of the 3rd ferromagnetic free layer 182 will be rotated toward the back of space so that it may be in a saturation state, as an arrow head 198 shows. The magnetic moment 192 of the 4th ferromagnetic free layer 184 is rotated on the outside of space, as an arrow head 200 shows. In the magnetic moment 200 of the 4th ferromagnetic free layer, out of space, since the magnetic moment 172 of the pinning layer 162 goes in the inner part of space, these are reverse parallel and resistance of the spin bulb sensor 132 becomes max to a sense current. As for the arrow head 194,196,198,200, the direction should become reverse when the field signal from a rotation disk is going out of [instead of the back of space] space.
[0027] Therefore, if the spin bulb read head 52 is exposed to one polar field, the spin bulb sensor 130 will generate one polar reply signal, and the spin bulb sensor 132 will generate the 2nd signal of antipole nature. Although the phase has separated from about 180 degrees of these reply signals mutually and it is discriminatorily detected by the differential amplifier 144, this differential amplifier compounds a reply signal and generates a strengthening reply signal without the noise which the sensor picked up for common mode noise removal. The laminating free layers 158 and 164 are indicated by U.S. Pat. No. 5408377 transferred to these people. In this invention, the antiferromagnetism layers 166 and 170 can be built with the same ingredient, and can set up the magnetic orientation during manufacture at coincidence.
[0028] As a conclusion, the following matters are indicated about the configuration of this invention.
[0029] (1) In MR read head equipped with the air bearing front face (ABS) The 1st and the 2nd spin bulb sensor which generate the response which has an opposite polarity in response to a field, The gap layer pinched between the 1st and 2nd spin bulb sensors, The 1st and 2nd leads connected to the 1st spin bulb sensor at the serial, The 1st and 3rd leads interconnect electrically including the 3rd and 4th leads connected to the 2nd spin bulb sensor at the serial. The 1st spin bulb sensor The 1st pinning layer which makes a boundary mutually [in order to form switched connection among them], and the 1st antiferromagnetism layer are included. The 2nd spin bulb sensor The 1st and 2nd antiferromagnetism layers are the MR read head characterized by carrying out pinning of the magnetic moment of the 1st and 2nd pinning layers in the same direction including the 2nd pinning layer which makes a boundary mutually [in order to form switched connection among them], and the 2nd antiferromagnetism layer.
(2) MR read head given in the above (1) characterized by the 1st and 2nd antiferromagnetism layers being the almost same ingredients which have the almost same blocking temperature.
(3) The compound MR read head and the induction write head to which an insulating stack and an induction coil are inserted between the 1st and 2nd pole pieces, and the 1st and 2nd pole pieces contain MR read head of a publication in the above (2) characterized by opening spacing by the write-in gap layer on the air bearing front face including the induction coil with which the combined head was embedded in the insulating stack.
(4) A combined head given in the above (3) characterized by the 2nd and 4th leads connecting the 1st and 2nd spin bulb sensors to juxtaposition over the differential amplifier including the differential amplifier.
(5) A combined head given in the above (4) characterized by connecting the 1st sense current source to the 2nd lead, and connecting the 2nd sense current source to the 4th lead including the 1st and 2nd sense current sources.
(6) In the magnetic-disk drive which contains the combined head of a publication in the above (5) The magnetic disk with which a drive is supported by the rotating type on a frame and a frame, The support for supporting a combined head so that it may be attached on a frame and may become a magnetic disk and conversion relation, A means to rotate a magnetic disk, and the positioning means for connecting with a support and moving a head to two or more locations to said magnetic disk, The magnetic-disk drive characterized by including a means to be connected to a head, a means to rotate a magnetic disk, and a positioning means, to exchange a combined head and a signal, to control a motion of a magnetic disk, and to control the location of a combined head.
(7) The 1st spin bulb sensor contains the 1st nonmagnetic electric conduction spacer layer and the 1st laminating free layer. The 2nd spin bulb sensor contains the 2nd nonmagnetic electric conduction spacer layer and the 2nd laminating free layer. The 1st spacer layer should be caught between the 1st laminating free layer and the 1st pinning layer. The 2nd spacer layer should be caught between the 2nd laminating free layer and the 2nd pinning layer. The 1st laminating free layer contains the 1st ruthenium layer inserted between the 1st and 2nd ferromagnetic free layers. Including the 2nd ruthenium layer whose 2nd laminating free layer was pinched between the 3rd and 4th ferromagnetic free layers, since the 1st and 2nd ruthenium layers are thin enough The 1st and 2nd ferromagnetic free layers join together by switched connection, and the 3rd and 4th ferromagnetic free layers join together by switched connection. Since the 2nd free layer has larger magnetization than the 1st ferromagnetic free layer and the 3rd ferromagnetic free layer has larger magnetization than the 4th free layer The 1st ferromagnetic free layer

follows in footsteps of magnetic rotation of the 2nd ferromagnetic free layer, and the 4th ferromagnetic free layer follows in footsteps of magnetic rotation of the 3rd ferromagnetic free layer. MR read head given in the above (1) characterized by pinching the 1st spacer layer between the 1st pinning layer and the 2nd ferromagnetic free layer, and pinching the 2nd spacer layer between the 2nd pinning layer and the 4th ferromagnetic free layer.
(8) MR read head given in the above (7) characterized by the 1st and 2nd antiferromagnetism layers being the almost same ingredients which have the almost same blocking temperature.
(9) The compound MR read head and the induction write head to which an insulating stack and an induction coil are inserted between the 1st and 2nd pole pieces, and the 1st and 2nd pole pieces contain MR read head of a publication in the above (8) characterized by opening spacing by the write-in gap layer on the air bearing front face including the induction coil with which the combined head was embedded in the insulating stack.
(10) A combined head given in the above (9) characterized by the 2nd and 4th leads connecting the 1st and 2nd spin bulb sensors to juxtaposition over the differential amplifier including the differential amplifier.
(11) A combined head given in the above (10) characterized by connecting the 1st sense current source to the 2nd lead, and connecting the 2nd sense current source to the 4th lead including the 1st and 2nd sense current sources.
(12) In the magnetic-disk drive which contains the combined head of a publication in the above (11) The magnetic disk with which a drive is supported by the rotating type on a frame and a frame, The support for supporting a combined head so that it may be attached on a frame and may become a magnetic disk and conversion relation, A means to rotate a magnetic disk, and the positioning means for connecting with a support and moving a head to two or more locations to said magnetic disk, The magnetic-disk drive characterized by including a means to be connected to a head, a means to rotate a magnetic disk, and a positioning means, to exchange a combined head and a signal, to control a motion of a magnetic disk, and to control the location of a combined head.
(13) MR read head given in the above (8) characterized by having the magnetic moment by which orientation of the magnetic moment of a pinning layer is perpendicularly carried out to ABS, and orientation of the 2nd and 3rd ferromagnetic free layers is carried out in the same parallel direction to ABS.
(14) MR read head given in the above (8) characterized by each ferromagnetic free layer being NiFe.
(15) MR read head given in the above (8) characterized by being the thickness each ruthenium layer of whose is 4-10A.
(16) MR read head given in the above (8) characterized by connecting the 1st sense current source to the 2nd lead, and connecting the 2nd sense current source to the 4th lead including the 1st and 2nd sense current sources.
(17) MR read head given in the above (16) characterized by having the magnetic moment by which orientation of the magnetic moment of a pinning layer is perpendicularly carried out to ABS in the same direction, and orientation of the 2nd and 3rd ferromagnetic free layers is carried out in the same parallel direction to ABS.
(18) MR read head given in the above (17) characterized by each ferromagnetic free layer being NiFe.
(19) MR read head given in the above (18) characterized by being the thickness each ruthenium layer of whose is 4-10A.
(20) The compound MR read head and the induction write head to which an insulating stack and an induction coil are inserted between the 1st and 2nd pole pieces, and the 1st and 2nd pole pieces contain MR read head of a publication in the above (19) characterized by opening spacing by the write-in gap layer on the air bearing front face including the induction coil with which the combined head was embedded in the insulating stack.
(21) A combined head given in the above (20) characterized by the 2nd and 4th leads connecting the 1st and 2nd spin bulb sensors to juxtaposition over the differential amplifier including the differential amplifier.
(22) In the magnetic-disk drive which contains the combined head of a publication in the above (21) The magnetic disk with which a drive is supported by the rotating type on a frame and a frame, The support for supporting a combined head so that it may be attached on a frame and may become a magnetic disk and conversion relation, A means to rotate a magnetic disk, and the positioning means for connecting with a support and moving a head to two or more locations to said magnetic disk, The magnetic-disk drive characterized by including a means to be connected to a head, a means to rotate a magnetic disk, and a positioning means, to exchange a combined head and a signal, to control a motion of a magnetic disk, and to control the location of a combined head.

[Translation done.]

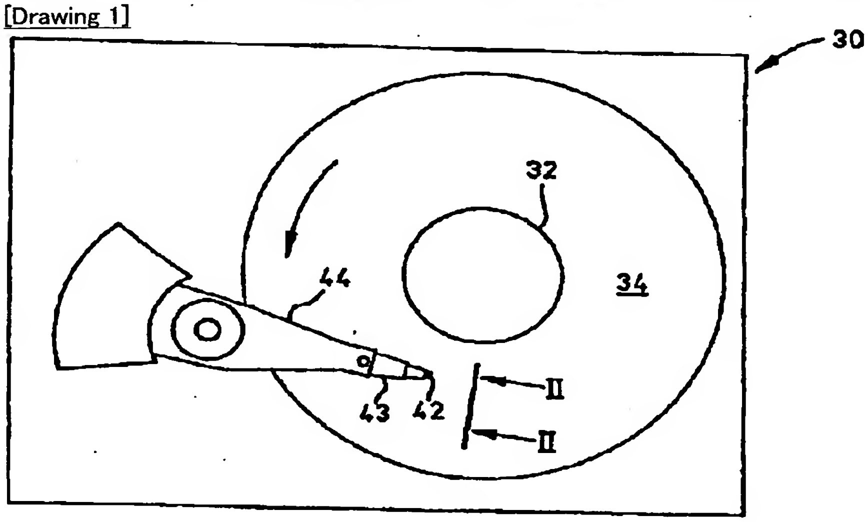
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the top view of a magnetic-disk drive.
[Drawing 2] It is drawing cut off along with flat-surface II-II of drawing 1 .
[Drawing 3] It is the side elevation of a magnetic-disk drive of drawing 1 .
[Drawing 4] It is drawing cut off along with flat-surface IV-IV of drawing 2 .
[Drawing 5] It is the ABS Fig. of the read head of drawing 4 cut off along with flat-surface V-V of drawing 4 .
[Drawing 6] It is the expansion outline ABS Fig. of the read head part of the spin bulb of drawing 5 .
[Drawing 7] It is the outline ABS Fig. of the spin bulb sensor of the advanced technology.
[Description of Notations]
52 Spin Bulb Read Head
130 1st Spin Bulb Sensor
132 2nd Spin Bulb Sensor
134 Gap or Insulating Layer
136 1st Lead
138 2nd Lead
140 3rd Lead
142 4th Lead
144 Differential Amplifier
146 1st Capacitor
148 2nd Capacitor
150 1st Sense Current Source
152 2nd Sense Current Source
154 1st Spacer Layer
156 Pinning Layer
158 Laminating Free Layer
160 Spacer Layer
162 Pinning Layer
164 Laminating Free Layer
166 Antiferromagnetism Layer (AFM)
168 Magnetic Orientation
170 Antiferromagnetism Layer (AFM)
172 Magnetic Orientation
174 Ruthenium (Ru) Layer
176 1st Ferromagnetic Free Layer
178 2nd Ferromagnetic Free Layer
180 Ruthenium (Ru) Layer
182 3rd Ferromagnetic Free Layer
184 4th Ferromagnetic Free Layer
186 Magnetic Moment
188 Magnetic Moment
190 Magnetic Moment
192 Magnetic Moment
194 Magnetic Moment
200 Magnetic Moment

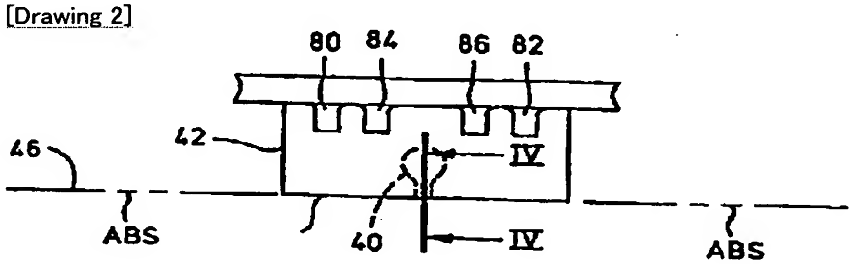
[Translation done.]

DRAWINGS

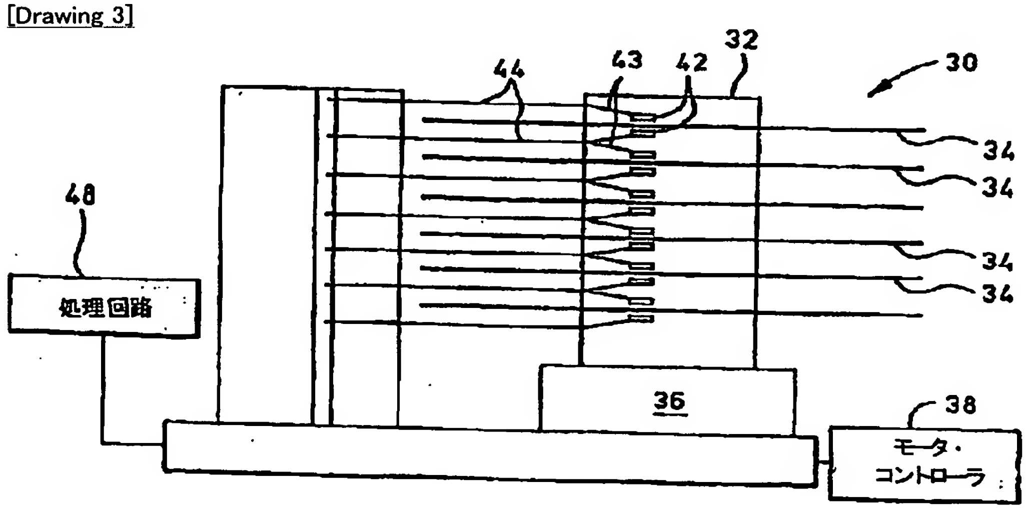
[Drawing 1]



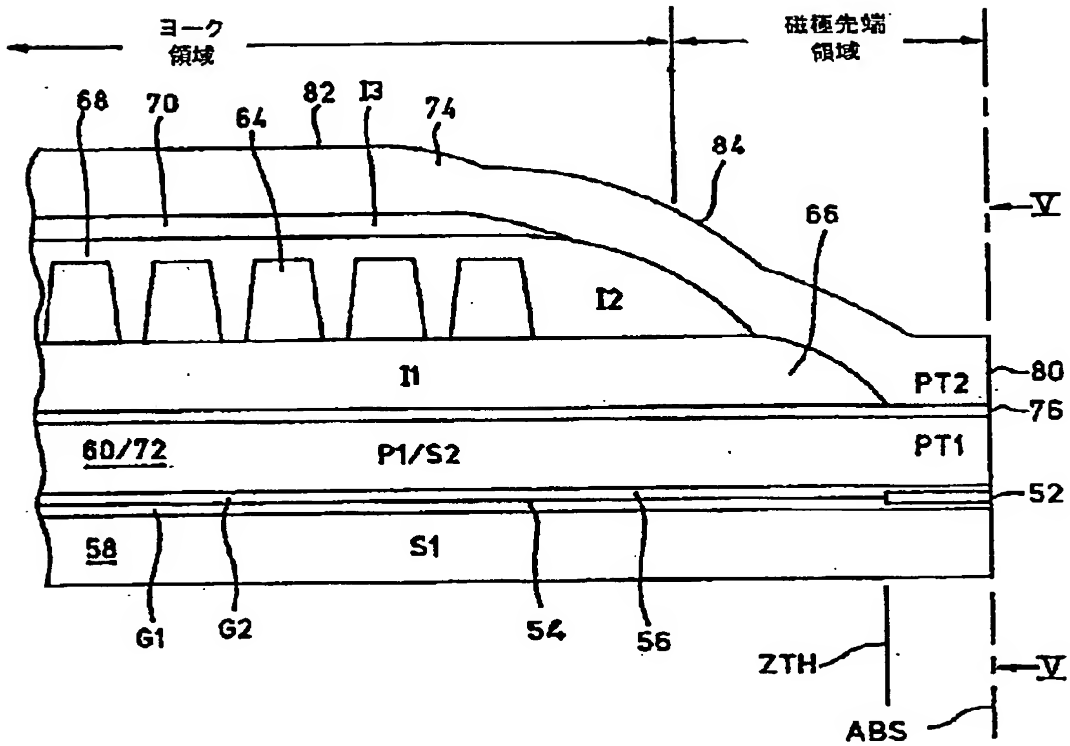
[Drawing 2]



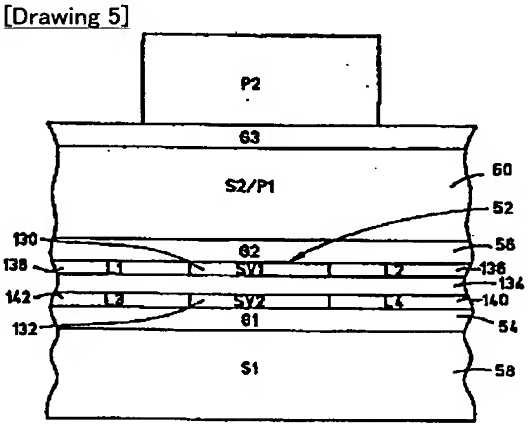
[Drawing 3]



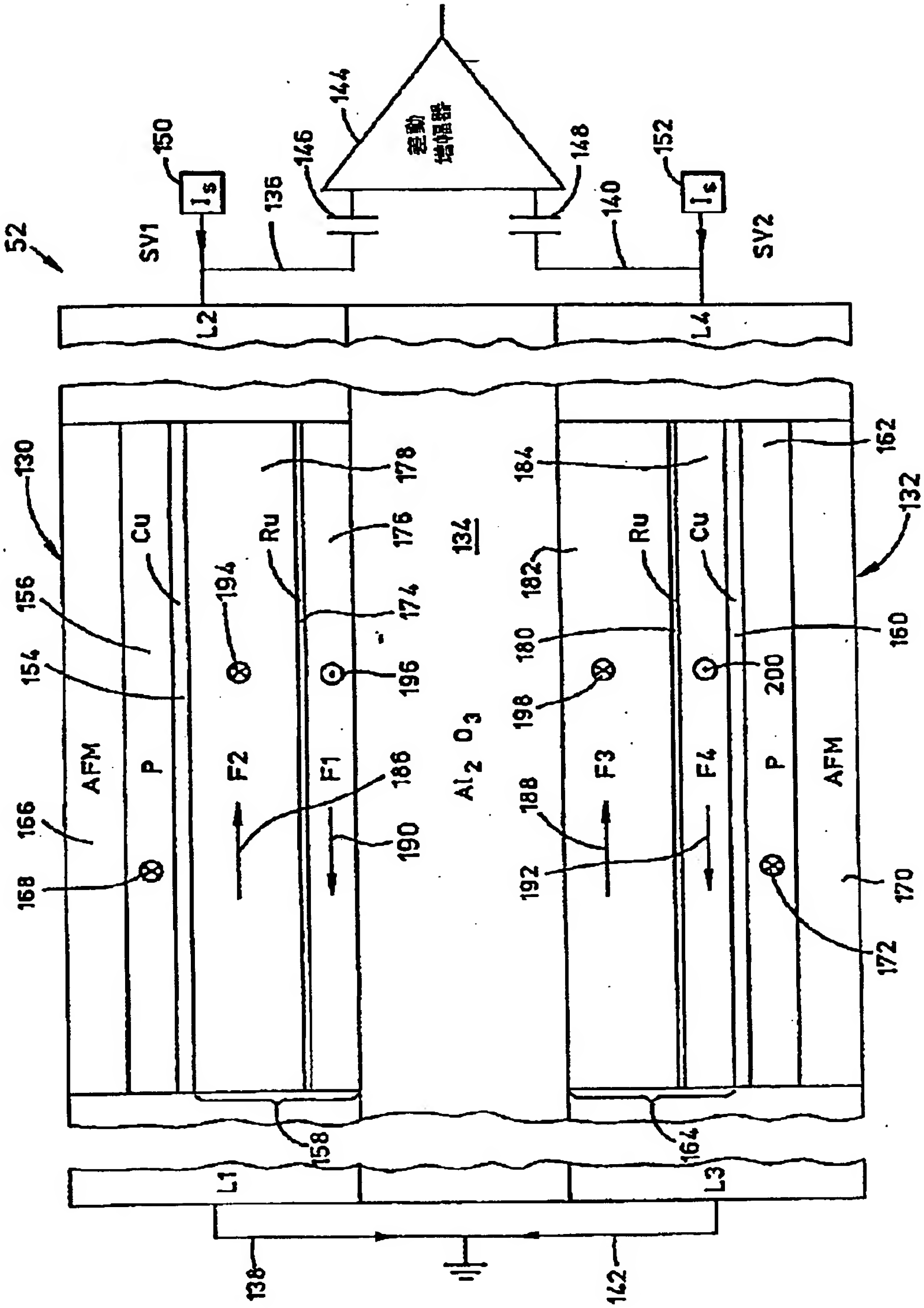
[Drawing 4]



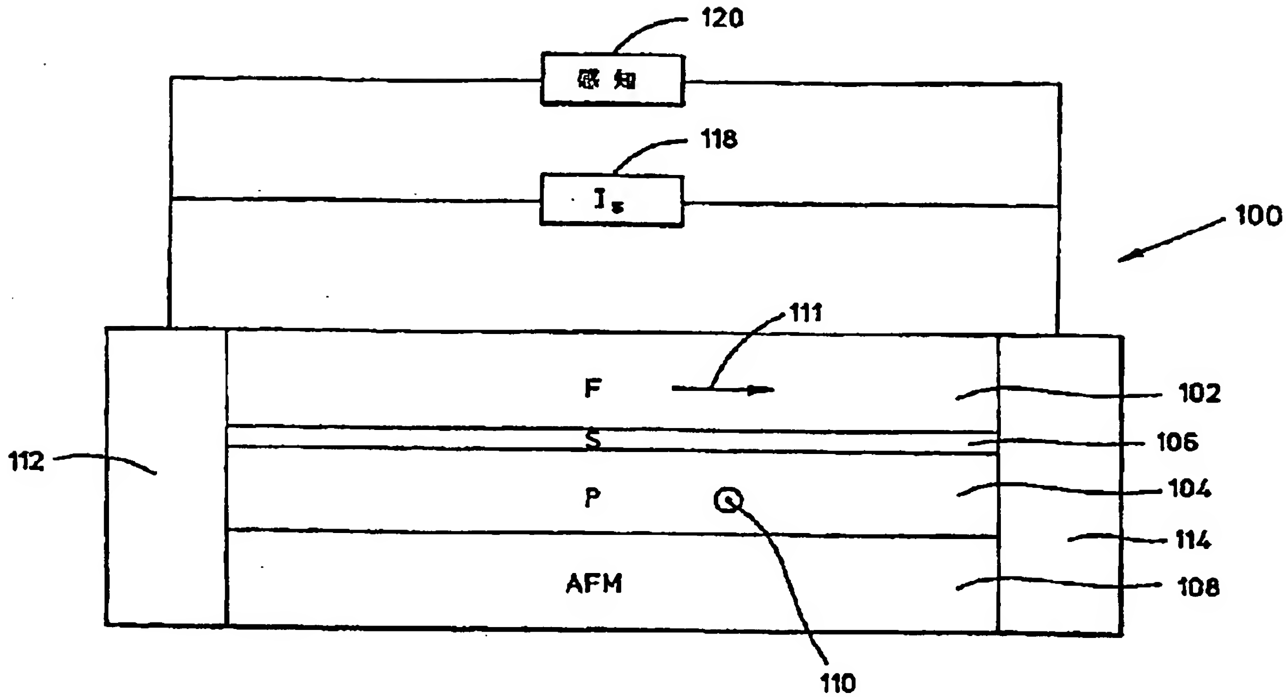
[Drawing 5]



[Drawing 6]


差動増幅器
144
146
148
150
152
I_s
I_s
136
140
52
SV1
SV2
L2
L4
130
132
134
Cu
Ru
Ru
Cu
AFM
P
F2
F1
Al_2O_3
F3
F4
P
AFM
154
156
158
160
162
164
166
168
170
172
174
176
178
180
182
184
186
188
190
192
194
196
198
200
L1
L3
138
142

[Drawing 7]



[Translation done.]